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Estimation of Response Times for Fire Fighting Personnel on a Naval Vessel

S.R. Kennett

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ABSTRACT

Times required for personnel to complete a range of simple movement tasks were measured on board a Type 12 Destroyer Escort, HMAS Derwent. Data were collected from observation of the crew going about their normal sea duties and movement of Aeronautical and Maritime Research Laboratory (AMRL) staff.

These times can be used to give an estimate of the movement time of fire fighters during a fire incident at sea.

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Executive Summary

Times required for personnel to complete a range of simple movement tasks were measured several years ago on board a type 12 Destroyer Escort, HMAS Derwent. The results of this work can be applied to other RAN ships. Data were collected from observation of the crew going about their normal sea duties as well as from the movements of Aeronautical and Maritime Research Laboratory (AMRL) staff and members of the crew performing specified tasks.

These data were collected to provide crew movement information for the models used in the fire management training program, FIREMAID, which is being developed for the Royal Australian Navy. In that program, fire behaviour and smoke propagation, as well as crew response, are simulated.

The data can also be used to provide an estimate of the time to evacuate the ship or a section of the ship under a variety of states of readiness.

Contents

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Stephen Kennett graduated from the University of Melbourne with a B.Sc. (Hons) in 1976, a M.Sc. (Nuclear Physics) in 1978 and a Ph.D. (Nuclear Astrophysics) in 1981. He commenced with the Department of Defence, Materials Research Laboratory, now the Aeronautical and Maritime Research Laboratory, Defence Science and Technology Organisation (DSTO) in 1981 and has undertaken research in interaction of lasers with materials, atmospheric optical propagation and laser eye protection. Since 1989 he has lead a research team working in the area of naval fire research.

1. Introduction

Fire has proved to be a major contributor to the loss of naval ships in combat and non-combat operations. Rapid response to the initial outbreak of fire is essential to the control of fire and this response depends, to a large extent, on the training of the fire fighting team and their mobility.

To aid training in the management of shipboard fires, the Royal Australian Navy (RAN) uses FIREMAID [1-3] as part of its courses for damage control officers and senior sailors. FIREMAID is a personal computer based real time simulation of fire incidents in which input from the trainee is used to deploy available resources against the fire. Fire behaviour and smoke propagation, as well as crew response, are simulated.

In a realistic ship fire simulation, it is necessary to model both the fire and the response of the crew. Standard fire models are available for modelling the fire spread and smoke flow [4, 5], however few data are available on the mobility of crews and the time it takes to perform on board tasks. Data for modelling the movement [6, 7] in building emergencies are available, however this is limited in its application to naval vessels.

Times required for personnel to complete a range of simple movement tasks were measured on board HMAS Derwent, a Destroyer Escort (DE), whilst the ship was participating in sea trials with her sister ship, HMAS Torrens. Data were collected from observation of the crew going about their normal sea duties and from Aeronautical and Maritime Research Laboratory (AMRL) staff and members of the crew performing specified tasks. The sea conditions remained calm throughout the data collection period and were not a factor considered here.

2. Movement Data

Movement through doors and hatches in naval vessels is controlled by a series of watertight control markings painted on each door and hatch. Three markings X, Y and Z indicate the conditions under which such a hatch or doorway can be opened. Doors and hatches marked with an X are to be kept closed in all watertight conditions. Doors and hatches marked with Y and Z can be opened at sea under some restrictions.

It is assumed that the movement of personnel through a ship can be divided into the performance of a sequence of small tasks and that their overall movement time can be estimated from the sum of the times to perform the component tasks.

Movement times through a ship are determined by access through narrow passageways, ladders and hatches and each of these are considered separately in the following sections.

Some tasks were repeated with sailors wearing a self-contained breathing apparatus with the aim of assessing how this item of equipment affects transit times. No measurements were taken in hot or smokey environments.

3. Passageways

Passages on naval vessels tend to be narrow with small head clearances. The main passage on deck 2, on the Type 12 Destroyer Escort HMAS Derwent, averaged 1.0 m in width and an effective height of approximately 1.8m limited by the presence of overhead electrical cabling. The main passage is not straight and a large amount of equipment is attached to the passage walls.

3.1 Transit Times Along A Passage

Transit times of crew were measured along the main passage on 2 deck between the doorways at 2J/K and 2F/G. These doors are secured open during normal sea duty and are 22.4 m apart.

Crewmembers were timed between the two doors in the normal course of performing their duties and were not aware of being timed. AMRL staff, aware of the timings and instructed to proceed between the two doorways, were also timed. Timing started as their front foot hit the deck between the two doorways and stopped as their back foot was lifted through the second doorway. No significant difference between timings of the two groups was observed.

One timing measurement was rejected because of the presence of two sailors talking in the passage, which obstructed movement. On this occasion the transit time was 24 seconds. Otherwise, the unobstructed passage of a single person dressed in normal work apparel (overalls and work boots) took 11.5 +- 0.7 seconds. The minimum time observed was 8.5 seconds.

The average unobstructed speed along the passage was 1.9 +- 0.1 m/s. This is greater than the data presented by Nelson and MacLennan [6, 7] of 1.4 m/s for evacuation

speeds along passageways in buildings but is consistent with 1.9m/s for escape groups in normally lit corridors as measured by Jin [8]. Jin postulates that walking speed may also depend on the degree of familiarity with the configuration of the corridor.

3.2 Passage Transit Times with Breathing Apparatus

The effect of wearing a breathing apparatus (BA) on the transit times of a female and male sailor was examined by repeating the previous experiment with and without BA. Both sailors were in their early twenties, physically fit and wore overalls and work boots. The male sailor was approximately 182 cm tall and the female sailor was 165 cm tall.

The sailors were asked to proceed at their normal walking pace through the doorway, along the passage and through the doorway at the other end. As in the previous section, timing started as their front foot hit the deck between the two doorways and stopped as their back foot was lifted through the second doorway.

There was no significant difference between the passage transit times of the two sailors with or without the BA. However the BA reduced the mobility of both sailors. Transit times along the passageway took an average time of 13.2 +- 1.1 s, 2 seconds longer than observed without the BA.

The average speed along the passage with BA was 1.7 +- 0.1 m/s.

4. Ladders

Two general access ladders were considered as being typical of ladders in naval vessels. Both ladders span from one deck to the next. The first was an external ladder between 1 deck and 2 deck, which did not pass through a hatchway. The second was an internal ladder where access was through a hatchway as can be seen in figure 1.

Figure 1. A sailor ascends an internal ladder on HMAS Derwent. The sailor, having practiced this climb before, rotates his upper body to allow the BA to pass quickly through the hatchway.

4.1 External Ladder

The time taken to negotiate an external ladder was obtained from sailors returning from 1 deck to their normal sea duties on 2 deck and below after a fire at sea exercise.

The ladder consisted of ten rungs and had a handrail. The ladder started and finished on an open deck. Nine sailors took a total of 38 seconds to descend the ladder. The timing was started as a sailor in the middle of a larger group waiting to access the ladder placed his foot on the ladder. The timing was stopped as the final contact of the ninth sailor behind him left the ladder.

The average time to descend the external ladder was 4.2 seconds.

4.2 Internal Ladder

Sailors and AMRL staff were timed both up and down an internal ladder between 2 deck and 1 deck. The ladder consisted of 10 rungs and spanned a height of 2.8 m at an angle 30 degrees from the vertical. The hatch at the top of the ladder was fixed open. Times were taken from the initial foot contact with the ladder until the final contact with the last rung.

Sailors were timed going up and down the ladder during their normal duties and were mostly unaware of being timed. Times varied from 3.0 to 8.0 s with an average time of 5.3 +- 0.3 s. The fastest time was of a tall; solidly built sailor aware of the timing experiment and who encountered no obstructions on his approach to the ladder.

4.3 Internal Ladder with BA.

The female and male sailor who had previously participated in the passage transit time measurements, were timed up and down an internal ladder between 2 deck and 3 deck. Each was dressed in overalls and wearing BA. The ladder consisted of 10 rungs and spanned a height of 2.8m and the hatch at the top of the ladder was fixed open. Times were taken from the initial foot contact with the ladder until the final contact with the top rung. The ladder configuration and timing arrangements was as described above. Timings varied from 5.1 to 10.0 s with an average time of 5.3 +- 0.3 s.

Figure 1 shows the male sailor, with the BA on, ascending the ladder. With practice he learnt that it was necessary to rotate his upper body to negotiate the hatch opening in order to stop the BA bottles impacting on the deckhead. Adoption of this process was reflected in the times he took to ascend the ladder which reduced rapidly from 10.0 to 5.1 seconds.

Similar adaptation to climbing the ladder was necessary by the female sailor, however her smaller frame allowed her to simply adjust her distance from the ladder. Her times decreased in a similar fashion.

5. Door and Hatch Entry

5.1 Class 'Z' access doors

A male sailor of medium build in normal crew working gear consisting of blue overalls and work boots, was tasked to make door entries. The sailor was instructed on a 'go' signal to proceed from one side of a clipped door to the other side and re-clip the door behind him.

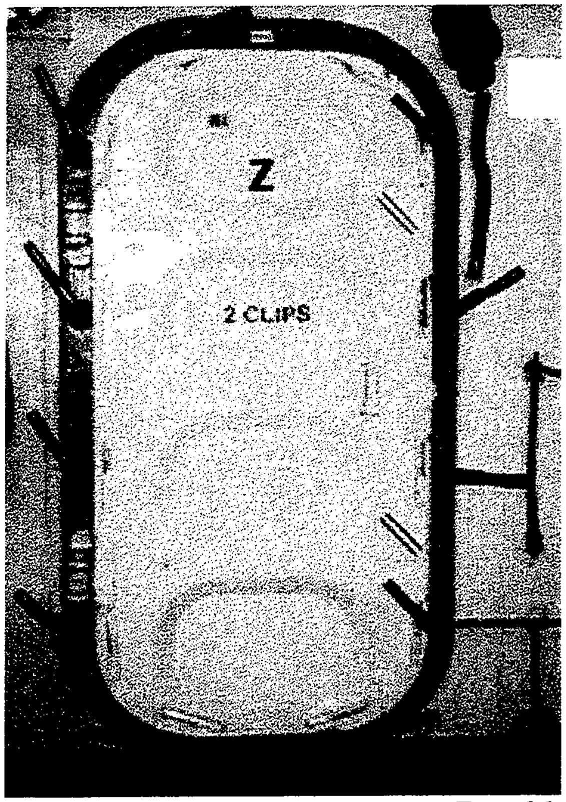

Figure 2 A typical access door on 2 deck of HMAS Derwent. Two of the clips are kept closed during normal cruising.

5.1.1 Door and 2 clips secured

Figure 2 shows a typical watertight door on the DE. Door entry timing was started with the sailor next to but not touching the door and stopped when the second clip was fully secured behind him. The process was repeated six times and the average time for this procedure was 6.2 +- 0.7 s.

5.1.2 Door and 12 clips secured

A door of the type seen in figure 2, with 12 clips closed, is described as a fully clipped door as would be found in a DE at action or emergency stations. A sailor was tasked to enter the fully clipped door and secure it behind him. Door entry timing was started

with the go signal and stopped when the last clip was shut fully. The process was repeated four times with an average time of 25.5 +- 2.2 s.

Times varied from 28 s to 22 s and improved with each attempt as the sailor refined his door opening and closing techniques. No significant improvement occurred after the third attempt.

5.2 Hatches

Times taken to negotiate hatches were measured. Sailors were instructed to enter various hatches and secure the hatch behind them. Three types of hatches were used, a large access hatch held by 6 clips, a large access hatch held by wing nuts and an escape hatch.

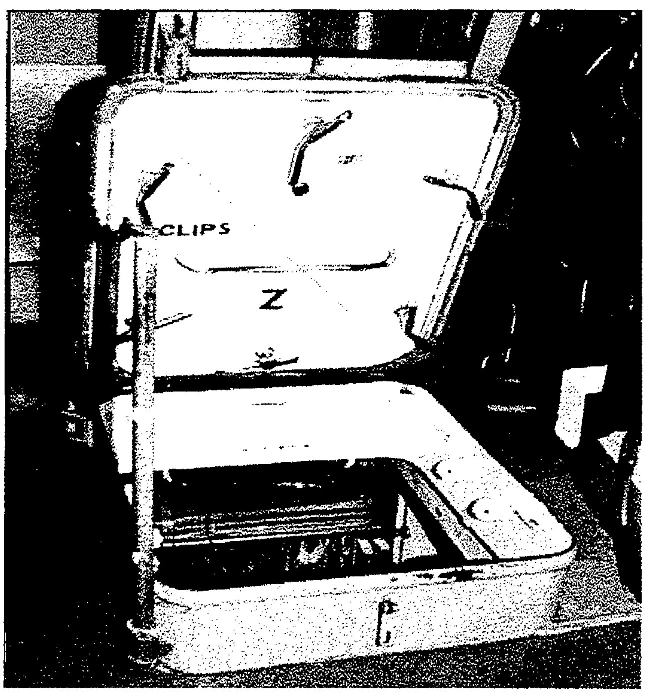

Figure 3. Internal hatch between decks in the open position. Six clips are used to secure this type of hatch.

5.2.1 Hatch with 6 clips

For a 6 clip hatch shown in figure 3, a sailor was timed performing 3 separate tasks.

First, the sailor was asked to open a hatch from above, climb down and close the hatch behind him. Timing ended with the closing of the sixth clip.

The sailor was then asked to open the hatch from below and climb to the deck above. The hatch was to be left in the open state. The signal to start the ascent was given by tapping the hatch and timing was started as the first clip started moving. The timing was stopped as the sailors trailing foot left the ladder.

Finally, he was required to close the hatch and close the clips from above.

Average times measured were as follows;
23 +- 2 s to open the hatch, climb down and close the hatch and secure with all 6 clips.
22 +- 2 s to open the hatch from below, and climb through.
A further 8.0 +- 0.6 s were required to close the hatch behind him and lock down the six clips.

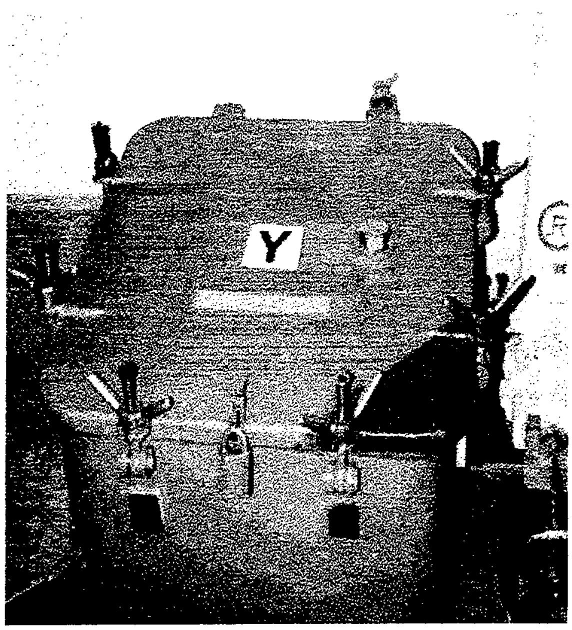

Figure 4 Hatches into rarely accessed stowage areas are often held down by butterfly nuts and can only be opened from above.

5.2.2 Wing clips 'Y' Access Hatches

Butterfly clips secure a number of hatches on the DE. A typical hatch of this type is shown in figure 4. Some hatches of the size and shape of figure 3 were also secured

with butterfly clips. The process necessary to descend through such a hatch is essentially the same as that required for hatches secured by the simpler clip arrangement except for releasing the butterfly clip. Rather than have the sailor open such hatches and descend through them, it was considered that the times to undo and close a single clip together with information from existing timing data would enable the time to descend through butterfly clip secured hatchways to be estimated.

Time to open a single butterfly clip 3.6 +- .3 s
Time to close a single butterfly clip 5.3 +- .3 s

There are 8 clips on these hatches which should take 29 +- 3 s to undo the clips and a further 6 +- 2 s to open the hatch and descend through it. This type of hatch is designed not to be closed from below.

5.2.3 Time through escape hatch.

Six officers and senior sailors volunteered to be timed through a typical escape hatch on the DE between decks. The hatch was approximately 80 cm in diameter with three clips securing it in place. Access to the hatch was provided by a rope ladder. A cover plate on the deck above hid the hatch and provided a flat surface for everyday use.

Figure 5 shows the emergency hatch in 3J mess used in the exercise. Figure 5a shows the same hatch and ladder from below. The ladder was coiled up and tied in place with a small section of cord. Figure 5b shows the cover plate of the hatch from above in the ship's wardroom.

A 'go' signal was given and timing started. The six people waiting below the hatch then proceeded to open the hatch and climb to the deck above. The timing was stopped as the last person cleared the hatch. The process was then repeated.

For the first run, a time of 58 s was obtained, at an average of 10 s per person. Difficulty was encountered in opening the hatch, which can only be opened by the first person to the hatch. Any assistance is blocked by the narrow access. The second time through was much smoother with an average of 6.5 s per person.

Figure 5 Emergency escape hatch used in timing measurements. A) Hatch as seen in deckhead of 3J mess. B) Hatch as seen in deck of wardroom.

6. Time to don BA.

The time it takes personnel to put on a breathing apparatus will depend on training. For the purposes of producing data for the FIREMAID computer training program, it was considered only necessary to time trained personnel. In the normal course of a training exercise the time taken to dress a member of the standing sea fire fighting party in standard Open Circuit Compressed Breathing Apparatus (OCCABA) was 54 seconds. This time was measured from the time of arrival at the BA equipment station to the completion of being fully dressed and checked.

7. Estimation of Transit Times through a Ship

The data collected in the previous sections and summarised in Table 1 can be used to estimate transit times of personnel through a DE or similar vessel.

For example, for a sailor to travel through from 1 deck aft to the AC space on 3 deck requires the sailor to travel down an external ladder, along the main passage on 2 deck though four doors and descend through 1 hatch.

If the doors are closed with two clips and the hatch is open the journey should take

6.2 * 4 +	(time to negotiate the doors)
23.0 +	(time to travel along the corridor)
4.2 +	(time to negotiate the external ladder from 1 deck to 2 deck)
5.3	(time to negotiate the internal ladder from 2 deck to 3 deck)

= 57.3 seconds

If the ship is at action stations then the doors and hatches are fully closed the journey should take

25.5 * 4 +	(time to negotiate the doors)
23.0 +	(time to travel along the corridor)
4.2 +	(time to negotiate the external ladder from 1 deck to 2 deck)
5.3 +	(time to negotiate the internal ladder from 2 deck to 3 deck)
22.2	(time to open hatch, descend though it, close and clip the hatch)

= 156.7 seconds

In the case of a team of sailors travelling the same path there should be added delays due to the time for the team to pass each obstacle being added to the time for the single sailor. The first sailor would open the door and the last would close it.

Considerable delays are generated when dealing with the transit of large numbers. An example was observed when HMAS Derwent was ordered to 'ship leaving stations' during an exercise at sea in which a fire incident was reported. The time to arrival at the appointed leaving ship station on the aft section of 1 deck took 87 seconds from the electronics operations room.

The collected data would have predicted time of

6.2 * 2 +	(time to negotiate the doors)
23.2 +	(time to travel along passageways and decking)
5.3 +	(time to negotiate internal ladder from 2 deck to 1 deck)

= 40.9 seconds for a single sailor.

This can be explained in the following example. Consider a collection of 10 sailors initially starting from the same location but moving off at 1 s intervals. The first sailor takes 5.3 s to arrive at the ladder. The second sailor will arrive 1 s later and wait for the first sailor to ascend the ladder. He will wait until the feet of the sailor in front of him clear his head, a wait of approximately 4 s. The third sailor, arriving 1 second after the second, will then have to wait for 3 s before the second sailor starts his ascent and a further 4 s for him to clear the ladder. For each subsequent sailor the waiting time increases by 3 s so that for the 10th sailor a wait of 28 s will be added to the duration of the journey. The ladder increases the interval between sailors, so that for subsequent obstacles no further delays occur. The 40.9 s for the single sailor is then increased to 69 for 10 sailors.

In the actual exercise, the exact numbers of men negotiating the ladder in that transit path and the starting points of each of the sailor is not known but a time of 87 s would suggest 15 or 16 sailors which would be quite consistent with crew numbers and that particular access way.

Table 1: Summary of timing results.

Test	*trials*	*Approach Direction*	*Control Marking*	*Distance travelled (m)*	*Timing (S)*	*Speed (m/s)*
	Door 2 clips		Z		6.2+-0.7	
	Door 12 clips		Z		25.5+-2.2	
	Hatch 6 clips	above below	Z		23+-2 22+-2	
	secure Hatch 6 clips	above	Z		8.0+-0.6	
	Butterfly clip	open close	Y		3.6+-0.3 5.3+-0.3	
	Escape Hatch	below	X		6.5	
	Passage no BA			22.4	11.5+-0.7	1.9+-0.1
	Passage BA			22.4	13.2+- 1.1	1.7+-0.1
	Ladder internal	above & below		2.8	5.3+-0.3	0.53+-0.3
	Ladder External	above		2.8	4.2	0.67

8. Discussion and Recommendations

Knowledge of times to perform simple tasks gives the ship designer and Navy an estimate of the time required for personnel to travel through a ship. From the times obtained here the minimum times required to prepare for and arrive at the scene of a fire on a warship can be estimated.

The reduction in the timings highlights the advantages in using emergency exits and escape hatches during training.

The time taken to perform tasks will be a function of sea state and the stability of the platform. Further studies should be carried out to fully map out the relationship between response times and sea state. In addition, studies should include the effects of reduced visibility due to the presence of smoke.

9. Acknowledgment

The author would like to thank the captain, Commander J. McAree, the officers and crew of HMAS Derwent for their full cooperation during the data collection. The author would also like to thank Mr J. Howe and Dr P. Lambrineas for their assistance during the data collection.

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19. ABSTRACT

Times required for personnel to complete a range of simple movement tasks were measured on board a Type 12 Destroyer Escort, HMAS Derwent. Data were collected from observation of the crew going about their normal sea duties and movement of Aeronautical and Maritime Research Laboratory (AMRL) staff.

These times can be used to give an estimate of the movement time of fire fighters during a fire incident at sea.

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